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# Investigating the empirical support for therapeutic targets proposed by the temporal experience of pleasure model in schizophrenia: A systematic review

Clementine J. Edwards *, Matteo Cella, Nicholas Tarrier, Til Wykes

*Department of Psychology, Institute of Psychiatry, Psychology & Neuroscience, Kings College London, UK*

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ABSTRACT

*Background:* Anhedonia and amotivation are substantial predictors of poor functional outcomes in people with schizophrenia and often present a formidable barrier to returning to work or building relationships. The Temporal Experience of Pleasure Model proposes constructs which should be considered therapeutic targets for these symptoms in schizophrenia e.g. anticipatory pleasure, memory, executive functions, motivation and behaviours related to the activity. Recent reviews have highlighted the need for a clear evidence base to drive the development of targeted interventions.

*Objective:* To review systematically the empirical evidence for each TEP model component and propose evidence-based therapeutic targets for anhedonia and amotivation in schizophrenia.

*Method:* Following PRISMA guidelines, PubMed and PsycInfo were searched using the terms "schizophrenia" and "anhedonia". Studies were included if they measured anhedonia and participants had a diagnosis of schizophrenia. The methodology, measures and main findings from each study were extracted and critically summarised for each TEP model construct.

*Results:* 80 independent studies were reviewed and executive functions, emotional memory and the translation of motivation into actions are highlighted as key deficits with a strong evidence base in people with schizophrenia. However, there are many relationships that are unclear because the empirical work is limited by over-general tasks and measures.

*Conclusions:* Promising methods for research which have more ecological validity include experience sampling and behavioural tasks assessing motivation. Specific adaptations to Cognitive Remediation Therapy, Cognitive Behavioural Therapy and the utilisation of mobile technology to enhance representations and emotional memory are recommended for future development.



## 1. Introduction

The ability to derive pleasure from activities is a key part of the human experience; it has positive effects on an individual's mood and increases motivation to engage with the world around them (Foussias et al., 2011; Frederickson, 2001). Hence any difficulty engaging with pleasurable experiences is likely to lead to reduced activity levels and social isolation. Social withdrawal and reduced functioning have been observed in individuals with schizophrenia, particularly those who report high levels of anhedonia (Krupa and Thornton, 1986).

Anhedonia is currently defined as a loss of the ability to feel pleasure and is considered to be part of the negative symptom cluster in schizophrenia which also includes apathy, avolition, asociality, poverty of speech and blunted affect (Kirkpatrick et al., 2006). Anhedonia is a stable trait in people with schizophrenia which persists independently of changes in positive symptoms, other negative symptoms and cognitive deficits (Berenbaum et al., 2008). Difficulty experiencing pleasure and motivational deficits are the most prominent among the negative symptoms in predicting poor functional outcomes (Foussias et al., 2011; Loas et al., 2009; Rocca et al., 2014). In at-risk and first-episode individuals, anhedonia has been shown to be an important predictor of future diagnosis of schizophrenia (Gelber et al., 2004; Velthorst et al., 2009). These data support anhedonia as a key therapy target but two recent reviews have concluded that the effectiveness of interventions which have reported an outcome for negative symptoms is very limited (Elis et al., 2013; Fusar-Poli et al., 2014). Indeed, both these reviews highlighted the lack of an evidence base for intervening in negative symptoms as a factor which contributes to the lack of targeted, effective treatments.

* Corresponding author.
*E-mail addresses:* clementine.edwards@kcl.ac.uk (C.J. Edwards), matteo.cella@kcl.ac.uk (M. Cella), nicktarrier228@gmail.com (N. Tarrier), til.wykes@kcl.ac.uk (T. Wykes).

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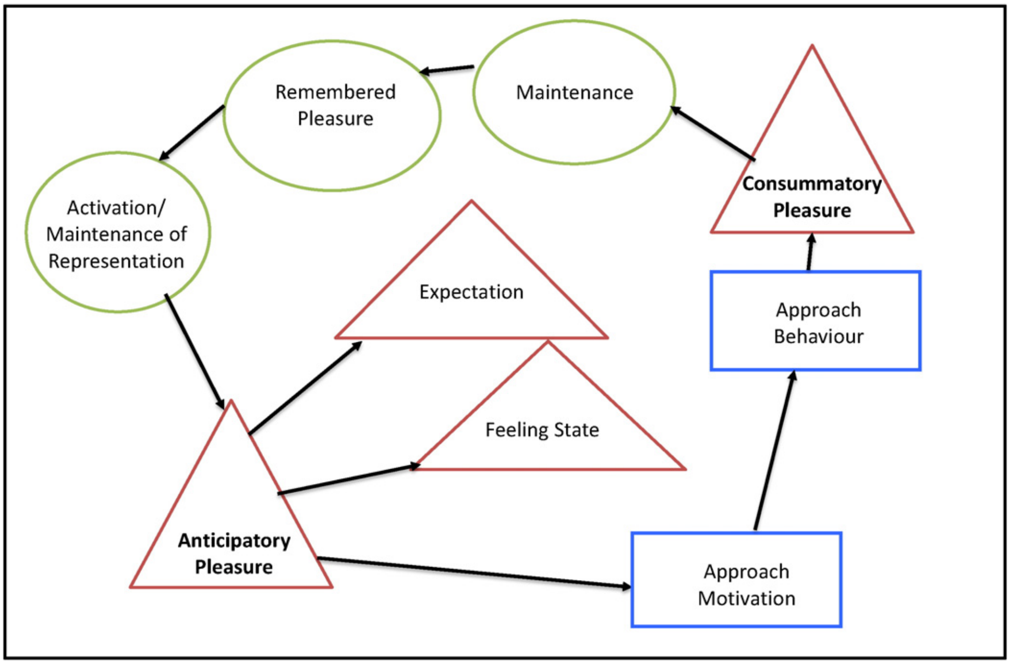


**Fig. 1.** The Temporal Experience of Pleasure Model.
(Kring and Caponigro, 2010).

The Temporal Experience of Pleasure model (see Fig. 1) includes an important distinction between intact consummatory ("in the moment") pleasure and a specific deficit in anticipatory pleasure experienced by people with schizophrenia (Kring and Caponigro, 2010). The model is cyclical and suggests that after an experience is initiated and enjoyed, the memory of that experience, and the ability to create and maintain a representation of it, contribute to anticipatory pleasure. Once pleasure has been anticipated, motivation to seek out and complete that activity is generated. The model has been extended to include findings from the reward and neuroimaging literature which proposes additional constructs such as value computation and effort computation for inclusion in the model (Kring and Barch, 2014). Research has focused on gathering evidence across several methodologies to support the concepts described in the model and this has been reviewed in two narrative papers (Cohen et al., 2011; Strauss et al., 2011). However, the TEP model proposes many constructs that contribute to the experience of pleasure and they have yet to be assessed systematically to detect which are empirically supported and should be prioritised as the foundation for an evidence-based intervention.

The aim of this review is to recommend interventions which may be effective on the basis of empirical evidence and highlight the gaps in knowledge that require further research. This will be achieved by systematically reviewing all experimental studies that include individuals with schizophrenia, measure anhedonia using a validated assessment tool and one of the components of the TEP model—consummatory pleasure, memory, executive functions/reward representation,: anticipatory pleasure or approach motivation and behaviours.

**Table 1**
List of psychometrically validated scales to assess anhedonia in schizophrenia.

| Name of measure | Reference: validation study |
|---|---|
| Positive and Negative Syndrome Scale | Kay et al. (1987) |
| Scale for the Assessment of Negative Symptoms | Andreasen (1982) |
| Physical and Social Anhedonia Scales | Chapman et al. (1976) |
| Temporal Experience of Scale | Gard et al. (2006) |
| Clinical Assessment Interview for Negative Symptoms | Horan et al. (2011) |
| Snaith Hamilton Pleasure Scale | Snaith et al. (1995) |
| Brief Negative Symptoms Scale | Kirkpatrick et al. (2011) |

## 2. Method

This systematic review was conducted following PRISMA guidelines (Moher et al., 2009), see Appendix 2 for a completed PRISMA checklist.

### *2.1. Study eligibility*

Studies were considered eligible if they:

- Included a majority of individuals with a diagnosis of schizophrenia according to the Diagnostic and Statistical Manual of Mental Disorder (American Psychiatric Association, 2013), Research Diagnostic Criteria (Spitzer et al., 1978) or International Classification of Diseases (World Health Organisation, 1992).
- Assessed anhedonia using validated instruments shown by at least one published validation study in people with schizophrenia (self-report or clinical interview; see Table 1).
- Were written in English
- Reported empirical data
- Did not only include individuals with primary co-morbid disorders e.g. substance abuse.

#### *2.1.1. Search criteria*

Both PubMed/Medline and PsycINFO were searched up to April 2015 by CE using the following keywords: schizophrenia and anhedonia. Alternative search terms for anhedonia (e.g. pleasure, positive affect, and reward) were excluded after initial searches produced a very high proportion of irrelevant papers (i.e. 90%). Studies that only included participants with co-morbid substance or alcohol abuse diagnoses (i.e. investigated the impact of these co-morbid diagnoses on emotional experience) were excluded as anhedonia may be present due to this primary diagnosis and thus confound the investigation of the nature of anhedonia in people with schizophrenia. This focus on anhedonia in the context of negative symptoms of schizophrenia and not as the result of affective disorders is also the reason for narrowing the search to "schizophrenia" only. Recently both a systematic review and meta-analysis (Elis et al., 2013; Fusar-Poli et al., 2014) have summarised the limited effectiveness of currently available interventions for negative

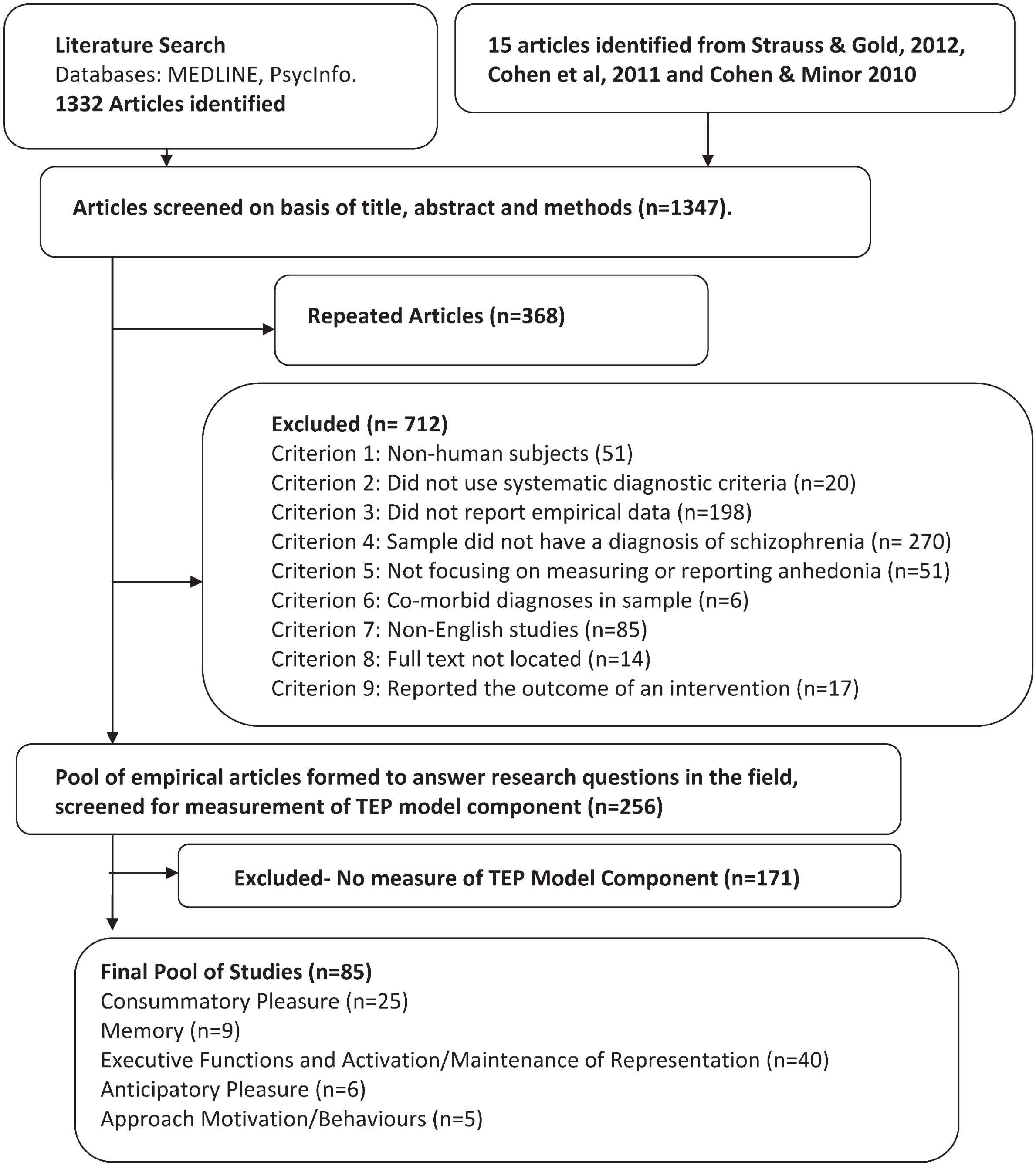


**Fig. 2.** Consort diagram of systematic search.

symptoms. Studies examining the effectiveness of an intervention were excluded from this review as the focus is on developing an evidence base for future interventions as both reviews state this is currently missing from the field. The abstracts of all the retrieved papers from these searches were initially scanned to exclude irrelevant papers. References of recent reviews and meta-analyses (published from 2010 onwards) were also hand-searched to identify any other possible relevant studies. The included studies were reviewed by the other authors.

The remaining empirical studies meeting the exclusion/inclusion criteria detailed in the method were reviewed and if a construct proposed in the TEP model (consummatory pleasure, memory, executive functions, working memory, anticipatory pleasure, approach motivation and behaviours) was measured then the paper was included. Each study was categorised by the TEP construct measured and the sample size (or number of studies if meta-analysis), measure of anhedonia, methodology, and main findings were extracted and entered into the full table of studies (See Appendix 1 for Table 1 and categorisation). Rating the quality of the included studies was considered, however, the heterogeneity of methodologies and variables across studies (e.g. fMRI, structural fMRI, Likert scales, experience sampling, smell identification test, event related potentials) resulted in the detailed data (rather than a single summary score) being more useful for a critical summary of the evidence (see Table 1). Synthesising the information in this manner allows for an assessment of the risk of bias when measuring each construct (i.e. small samples, use of a limited measure). Incorporating the main findings from each study in this table allows publication bias (e.g. towards positive findings) to be considered.

## 3. Results

The initial search identified 1332 potentially eligible studies. The references of three recent reviews (Cohen and Minor, 2010; Cohen et al., 2011; Strauss and Gold, 2012) produced another 15 potentially eligible studies. Once duplicates had been removed a total of 968 abstracts were screened. Studies were not considered if the full text could not be retrieved (n = 14), were not written in English (n = 85), did not use systematic diagnostic criteria (n = 20), a validated assessment of anhedonia (n = 51), examined the effectiveness of an intervention (n = 17) or studied primary co-morbid disorder (n = 6). Articles with unclear relevance were discussed with other authors. As a result of the selection criteria 256 papers detailing the results of 250 independent studies were finally considered (see Fig. 2).

A large proportion of the included studies (30%) reported either the prevalence or prognostic implications of anhedonia in people with schizophrenia. These results show that anhedonia is a stable symptom in individuals with schizophrenia (Buck and Lysaker, 2013; Dollfus and Petit, 1995; Horan and Blanchard, 2003) and high levels predict worse functional outcomes (e.g. Horan and Blanchard, 2003). These findings are well established and will not be discussed further.

### 3.1. Measures of anhedonia

20 studies were retrieved in the search which assessed or validated a measurement of anhedonia (see Table 1) and these differed in their specificity for the severity of anhedonia. Traditional symptom measures, the Positive and Negative Syndrome Scale PANSS and Scale for the Assessment of Negative Symptoms include anhedonia in the negative symptom ratings provided by this scale. As a result, it is often confounded with activity levels and other negative symptoms such as asociality and amotivation. Newer measures, the Clinical Assessment Interview for Negative Symptoms and Brief Negative Symptom Scale, focus on measuring anhedonia separately from other negative symptoms and independently from the activity levels reported by that individual. The Chapman scales were developed as an assessment of schizotypy and as such are grounded in assumptions that may not apply to people with a diagnosis of schizophrenia e.g. close friendships, family support and the opportunity to engage in activities. The Temporal Experience of Pleasure Scale (TEPS) is similar; it has been designed for use in both control and clinical populations and as a result assumes experiences occur in both groups which may not be the case in the clinical group. In particular there may be fewer opportunities for eating out, rollercoasters, and holidays. It also assesses consummatory pleasure using questions such as "I love it when people play with my hair" which may have limited validity as these experiences are not occurring "in the moment". The Snaith Hamilton Pleasure Scale (SHAPS) is used rarely in the literature, it does focus on anhedonia more specifically but without replication it is difficult to assess its performance as compared to the other available measures.

### 3.2. Consummatory pleasure

The finding that pleasure during activities or stimuli presentation is intact in people with schizophrenia is the most consistent in this field. A variety of methods have been used to measure anhedonia experimentally "in the moment" in the studies retrieved including: images, video clips, food, faces, words, sounds, smells and mood induction (Burbridge and Barch, 2007; Horan et al., 2006; Strauss and Herbener, 2011; Trémeau et al., 2009). In all studies the participants rated how pleasant they found the stimuli and individuals with schizophrenia reported similar levels of pleasure to controls, this is confirmed across studies in two meta-analyses (Cohen and Minor, 2010; Yan et al., 2012). This finding was replicated for arousal ratings (Llerena et al., 2012). These results suggest that enjoyment of experiences "in the moment" is intact, an important consideration in the development of a therapy. Clinicians may be able to capitalise on current experience if they are targeting related processes such as anticipation. Although this is a well-established finding it is important to note that the stimuli rated in an experimental context are carefully controlled and often selected from a small group of standardised stimuli e.g. International Affective Picture Scale (Lang et al., 1999). This method of measuring pleasure has limited real-world application but is valuable in studying short-term emotional responses. Technology has now been established to provide a focus on everyday ratings of enjoyment using experience sampling methodology (ESM) which overcomes this limitation. In ESM studies questionnaires are completed several times a day prompted by a smartphone, digital watch or pager and so this methodology captures "in the moment" experience during everyday life. One study conducted an ESM study using phone calls 4 times a day to assess consummatory pleasure and replicated the finding of similar enjoyment in people with schizophrenia and controls (Sanchez et al., 2014). This was in the context of increased negative mood in people with schizophrenia which had a weaker relationship with current enjoyment than in controls. The results are highly applicable to real-world scenarios.

### 3.3. Memory

The TEP model proposes that following an activity, the memory of the pleasure experienced and the details of the event, contribute to anticipating future pleasure. It has therefore been hypothesised that those individuals with schizophrenia who have poorer memory will also report higher levels of anhedonia.

Several studies examined this relationship through memory task performance and self-report measures of anhedonia (see Table 2). The results are inconclusive with some authors reporting impairment in visual and recognition memory associated with anhedonia (Brebion et al., 2007; Brebion et al., 2012; Kemali et al., 1987) but others reporting intact, if not superior, non-spatial, implicit and recognition memory associated with higher levels of anhedonia in individuals with schizophrenia (Brebion et al., 1999; Harvey et al., 2009; Stevens et al., 2002). The conclusions from these studies are limited as all those conducted by Brebion and colleagues include the same participants and the others include small samples (n < 30). These small sample sizes also limit the power of the studies to detect small-moderate correlations. As a result more indirect links, perhaps with other factors in the model acting as mediators or moderators, between anhedonia and emotional memory may be missed in these studies. Clearer hypotheses regarding the types of memory potentially involved e.g. memory for positive experiences, autobiographical memory and newer, more specific, measures of anhedonia (e.g. CAINS, BNSS) would enhance the validity and rigour of the studies conducted.

Studies assessing emotional memory i.e. remembering the emotions experienced during a previous event, report a consistent deficit in people with schizophrenia which is associated with self-reported anhedonia (Herbener, 2008). One study (Herbener et al., 2007) with a larger sample than those studies with negative findings (n = 33) demonstrated that, unlike in healthy controls, positive emotion did not enhance delayed recognition memory but negative emotion did. This suggests that the emotional memory deficit may be specific to positive emotions — an important detail to note in the development of an intervention. Support for the link comes from studies on the brain where the hippocampus and amygdala play key roles in the encoding-retrieval processes in emotional memory (Cohen et al., 2011). Activation in these regions is correlated with self-reported anhedonia during tasks involving emotional memory (Becerril and Barch, 2011; Dowd and Barch, 2010). Emotional memory is therefore a potential target for future interventions with a strong evidence base supporting its relevance to anhedonia.

### 3.4. Executive functions and representation activation/maintenance

The TEP model proposes that a representation of previous experiences and associated pleasure is activated and maintained to inform anticipatory pleasure. It has been suggested that the difficulty in building or activating these representations may underlie high levels of self-reported anhedonia (Burbridge and Barch, 2007; Cohen et al., 2011). Individuals with schizophrenia may also struggle to access the representation even if it is intact and maintained. These deficits would result in difficulties in using prior experiences when anticipating and therefore produce a failure to learn which activities had been enjoyable in the past. Individuals experiencing these problems are unlikely to repeat enjoyable activities (often seen in individuals with schizophrenia).

The difficulty in building or activating representations is hypothesised to be due to the well-documented executive function deficits (Burbridge and Barch, 2007). However, there is little behavioural evidence to support an association between executive functions and self-reported anhedonia (See Table 3). In the studies considered in this review, we found no significant correlations between levels of anhedonia and performance on executive functioning tasks including the Wisconsin Card Sorting task, the Verbal Fluency Test or the Stroop task e.g. (Larquet et al., 2010; Laurent et al., 2000). It is striking that the majority of these studies used the Chapman psychosis proneness scales which are designed for use in non-clinical populations to assess schizotypy and may not therefore accurately capture the experience of individuals with schizophrenia i.e. asking them to rate scenarios that assume they have close friends or access to leisure activities. Replication with newer, more appropriate measures designed for clinical participants would more accurately reflect the relevance of this cognitive domain for anhedonia. A large proportion of the studies included in the table did not measure anhedonia in the healthy control group. In those studies which did include an appropriate measure for the control group, such as the Chapman Scales, the majority did not report analyses assessing the association between executive function and anhedonia. This is problematic as it limits the conclusions that can be drawn regarding the deficits in people with schizophrenia. The neuropsychological tasks used e.g. the Wisconsin Card Sorting Task, the Go NoGo task, may also not be associated with self-reported anhedonia because they do not have an emotional component.

The neuroimaging literature shows different results. Reduced activation has been reported in the dorsolateral prefrontal cortex, ventromedial prefrontal cortex, orbitofrontal cortex and the ventral anterior cingulate cortex during emotive or reward processing tasks that correlates with high levels of self-reported anhedonia (Dowd and Barch, 2012; Park et al., 2015; Park et al., 2009; Ursu et al., 2011; Wang et al., 2003) although two studies with smaller sample sizes did not find these links (Gradin et al., 2011; Simon et al., 2010) and one reported a link with avolition but not anhedonia (Mucci et al., 2015). The majority of evidence from this group of studies suggests that deficits in executive functions in schizophrenia are associated with high levels of anhedonia. However, these findings are the result of correlational analyses and not group-comparisons which reduces the strength of this conclusion.

These regions of the brain also are implicated dopaminergic transmission involved in the process of anticipating future pleasure, see the following papers for a review (Gold et al., 2008; Kring and Barch, 2014; Strauss et al., 2013). The association between dopamine and anticipatory pleasure will be discussed in detail in the “Anticipatory Pleasure” section of this review. Gambling and reward-based tasks were used in these studies which increase the emotional content and therefore relevance to everyday life. These tasks are also more emotive than the neuropsychological tasks used in the behavioural studies described above and are therefore a more specific assessment of behaviours related to emotive rewards. Increased relevance to everyday life in comparison to neuropsychological assessments may explain the differing results using these two methodologies. Future research should be conducted with laboratory tasks containing an emotional component to gain a fuller understanding of any deficits in executive functions that may contribute to anhedonia.

Experimental tasks also need to be developed which measure the processes involved in creating and maintaining representations. In one such task participants rated the emotional intensity of an image and then repeated this rating after a 3 s delay (Gard et al., 2011). Individuals with schizophrenia were less consistent in their ratings across the delay than controls, demonstrating a deficit in representation maintenance of the pleasure experienced over a very short delay. A recent study used the Sensory-Specific Satiety Task to demonstrate that individuals with schizophrenia have difficulty accurately updating their representations of value compared to controls (Waltz et al., 2015). In the task people with schizophrenia did not show a satiety effect specific to the stimuli experienced unlike controls. Future research should prioritise dynamic tasks such as these which examine how reward representation changes over time. A further advantage of the development of innovative tasks such as these is that the conclusions drawn are based on group comparisons and effect sizes and not correlational analyses. This strengthens the rigour of the studies conducted and the reliability of the findings.

Although extensive research has been conducted into improving cognition in people with schizophrenia (Wykes et al., 2011), no studies have yet reported the effect that an improvement in executive functions has on the experience of pleasure.

### *3.5. Anticipatory pleasure*

This component of the TEP model has been the major theoretical driving force in the last two decades. Surprisingly, despite this focus in the theoretical literature, the majority of direct evidence for an anticipatory pleasure deficit comes from findings using the TEPS and not experimental tasks. This self-report measure asks participants to rate the truth of a series of statements (e.g. I look forward to a lot of things in my life) categorised as anticipatory or consummatory. The majority of studies report significantly lower anticipatory pleasure subscale scores in people with schizophrenia compared to controls and individuals with low negative symptoms but similar consummatory pleasure (Chan et al., 2012; Gard et al., 2007; Mote et al., 2014). One study, however, reports the opposite finding (Strauss et al., 2011) and the authors hypothesise that this may be due to the anticipatory ratings being more influenced by other factors (e.g. mood) and therefore less reliable across studies than the consummatory ratings.

One small study extends the use of self-report measures by using experience sampling methodology. This study reported reduced anticipatory pleasure in everyday life in the schizophrenia group compared to controls, alongside intact consummatory pleasure (Gard et al., 2007). Although the opposite finding of increased anticipatory pleasure in people with schizophrenia compared to controls was reported in a recent, larger ESM study (Gard et al., 2014). The findings from this study and self-report measures support anticipatory pleasure as potential therapeutic target but self-report alone is a narrow evidence base on which to develop an intervention as it is susceptible to both memory deficits and desirability biases.

Despite the substantial evidence from studies using self-report, experimental studies have so far failed to replicate them. Tremeau and colleagues conducted two studies using the same method. Participants were told details of the task they were about to complete and asked to rate how much they thought they would enjoy it (Trémeau et al., 2010; Trémeau et al., 2014). The study findings were different and neither supported a reduced anticipatory pleasure response. In the first study individuals with schizophrenia were no different to controls and in the second their anticipatory pleasure was increased compared to controls. Choi et al. (2013) also showed no differences in their anticipation in a task where participants preview a film prior to the full length feature. These experimental tasks are the beginning of an expanding field and may be limited by their use of previews and descriptions to generate anticipatory pleasure ratings. The more common process in everyday life is to use prior experience to generate emotional predictions regarding future events. Targeting this process may reveal specific deficits in schizophrenia as well as being more ecologically relevant.

It is hypothesised by Kring and Barch (2014) that the role of dopamine in signalling prediction errors may contribute to the anticipatory

**Table 2**
A table reporting correlations between scores on tasks assessing memory and anhedonia scores.

| Study | Task | Type of memory assessed mean score (SD) | Anhedonia measure mean score (SD) | Participants | Results |
|---|---|---|---|---|---|
| Relation between emotional face memory and social anhedonia in schizophrenia (Harvey et al., 2009). | Emotional face recognition memory task. | Emotional face recognition memory-recognition accuracy and response bias.<br>SZ<br>Recognition Accuracy = 0.31–0.42 (0.12–0.16).<br>Response Bias = −0.05 to −0.13 (0.21).<br>Controls<br>Recognition Accuracy = 0.35–0.52 (0.12–0.17).<br>Response Bias = −0.14 – .02 (0.18–0.21). | Chapman scales 11.1 (5.6) | 29 patients with schizophrenia and 27 matched healthy controls. | *No significant correlations* with social anhedonia scores and memory performance variables in the patient or control group (ps > .01 required for significance). |
| Visual memory errors in schizophrenic patients with auditory and visual hallucinations (Brebion et al., 2007). | Visual memory task. | Visual recognition memory.<br>Spatial context memory.<br>Discrimination accuracy: black & white = .56 (0.23) colour = .59 (.23–.24) Response bias = b&w = .34 (.22) colour = .36 (.22). Spatial errors = b&w = 3.51 (1.90) colour = 3.98 (1.72). | SANS<br>Mean not reported. | 41 schizophrenia patients. | Anhedonia *significantly correlated* with a *reduction* in false recognition errors (p < .005). Spatial context errors *not significantly associated* with anhedonia. |
| Failure of positive but not negative emotional valence to enhance memory in schizophrenia (Herbener et al., 2007). | 24 hr image recognition task | Long term recognition memory | Chapman scales Social anhedonia = 13.29 (7.66) Physical anhedonia = 16.23 (8.09). | 33 patients with schizophrenia, 28 healthy controls. | Analyses between anhedonia scales and recognition accuracy not conducted. |
| Temporal context discrimination in patients with schizophrenia: associations with auditory hallucinations and negative symptoms. Brebion et al., 2007 | List discrimination task. | Temporal memory for verbal stimuli (words) - memory of order in which they were presented- 1st list or 2nd list.<br>SZ<br>Misattributions of previous-list to the recent list: High freq words = 2.76 (1.39) Low freq words = 2.49 (1.48)<br>Misattributions of recent-list words to the previous list: High-freq words = 2.93 (1.17)<br>Low-freq words = 2.34 (1.49) Controls<br>Misattributions of previous-list to the recent list: High freq words = 1.91 (1.62) Low freq words = 1.63 (1.50)<br>Misattributions of recent-list words to the previous list: High-freq words = 2.00 (1.51)<br>Low-freq words = 1.77 (1.41) | SANS 20.3 (14.6) | 41 outpatients with schizophrenia, 43 healthy controls. | Affective flattening and anhedonia significantly *inversely correlated* with errors on this task i.e. a higher anhedonia score was associated with a better performance (p < .009).<br>No measure of anhedonia conducted in controls. |
| Does anhedonia in schizophrenia reflect faulty memory for subjectively experienced emotions? Horan et al., 2006 | Foods and film clips-pleasure ratings and delayed recall test. | 4 hr delayed discrimination task- recognition of stimuli and free recall of previous pleasure ratings. | Chapman scales physical anhedonia = 19.3 (7.5)<br>Social anhedonia = 17.5 (8.7) | 30 schizophrenia patients. 31 healthy controls. | *No significant differences* between patients and controls in immediate ratings or the recall of these ratings. No results reported for anhedonia and accuracy of recognition. |
| Hallucinations, negative symptoms, and response bias in a verbal recognition task in schizophrenia. Brebion et al., 2005 | Word recognition task. | Immediate verbal recognition memory (short-term). Delayed (5 min) verbal recognition memory (long-term). Delayed (5 min) verbal free recall. Recognition accuracy = .45 (.17) Response bias = .25 (.13). | SANS<br>20.5 (14.7) | 40 patients with schizophrenia. | Higher levels of anhedonia *significantly negatively correlate* with global false recognitions (p < .05), significant for delayed (r = 0.33, p < .05) and trend for immediate (r = −.3, p < .08). |
| Implicit and explicit learning in schizophrenics treated with olanzapine and with classic neuroleptics. Stevens et al., 2002 | Serial reaction time task Eye-blink conditioning Explicit visuospatial memory. | Implicit sequence learning. Correct responses (%) Classic NLs 1st half = 94 (6.2) 2nd half = 91.3 (9.4) Olanzapine 1st half = 94.6 (3.5) 2nd half = 94.7 (3.4) Implicit learning. Median trials to reach criterion. Classic NLs = 16 Olanzapine = 15 Spatial memory. Correct responses (%) Classic NL = 73 (10.5)<br>Olanzapine = 75 (12.3) | SHAPS<br>Classic NLs = 8.3 (1.1)<br>Olanzapine = 7.6 (0.8)<br>SANS Classic NLs = 11.2 (9.3) Olanzapine = 12.1 (17.2) | 25 patients with schizophrenia treated with olanzapine 25 patients with schizophrenia taking classic neuroleptics, 25 healthy controls. | SANS and SHAPS did not differ between patient groups. No measure of anhedonia in control group. Anhedonia measures *did not correlate* with any of the learning performance scores (rs < .02, ps > .05). |

*(continued on next page)*

**Table 2** (*continued*)

| Study | Task | Type of memory assessed mean score (SD) | Anhedonia measure mean score (SD) | Participants | Results |
|---|---|---|---|---|---|
| Opposite links of positive and negative symptomatology with memory errors in schizophrenia. Brebion et al., 1999 | Free recall task and two recognition tasks—intentional and incidental. | Free verbal recall. Number of intrusions = 1.76 (3.30). Number of list errors = 1.39 (1.56) Intentional delayed recognition memory (1 min). Decision bias = 0.30 (0.18) Delayed incidental recognition memory (5 min). Decision bias = 0.30 (0.19) | SANS 8.39 (4.32) | 33 schizophrenia patients and 40 healthy controls. | *Fewer* intrusions in free recall *significantly associated* with higher levels of anhedonia ($r = -0.42$, $p < .025$). *Lower* decision bias (better performance) in recognition task *significantly associated* with anhedonia ($r = -.55$, $p < .001$). No measure of anhedonia in control group. |
| Production of Atypical Category Exemplars in Patients with Schizophrenia (Brébion et al., 2010). | Reality monitoring task—typicality of responses—sematic memory. | Not reported | SANS Anhedonia 6.8 (4.5) | 41 people with schizophrenia, 43 controls. | *Anhedonia significantly predicted* the typicality of responses in the task. No measure of anhedonia in the control group. |
| Source memory errors in schizophrenia, hallucinations and negative symptoms: A synthesis of research findings (Brebion et al., 2012). | Recall and Recognition Memory Tasks of words and pictures. | Verbal memory accuracy words 20.5 (8.4) Recognition Index Pr 0.45 (0.17) Verbal Memory Errors Extra-List Intrusions 1.46 (1.85) Intra-List Intrusions 0.46 (1.1) Verbal response bias Br 0.25 (0.13) List discrimination errors 10.5 (3.2) Visual Memory Accuracy Visual Recognition Index Pr 0.57 (0.21) Visual Memory Errors Visual response bias Br 0.35 (0.18) Spatial context errors 7.5 (3.3) Source Memory Accuracy Pr-words 0.62 (0.24) Pr-pictures 0.67 (0.22) Pr-imagination 0.36 (0.23) Source Memory Errors Br-words 0.24 (0.17) Br-pictures 0.18 (0.19) Br-imagination 0.43 (0.22) Category production Typicality score 12.1 (4.6) | SANS Anhedonia 6.8 (4.5) | 41 people with schizophrenia, 43 controls. | *Anhedonia significantly inversely correlated* with verbal response bias ($r = -.36$), list discrimination errors ($r = -.46$), visual response bias ($r = -.46$), source memory response bias ($r = -.53$) and typicality production scores ($r = -.51$). No measure of anhedonia in control group. |

pleasure construct in the TEP Model. Abnormal prediction error signalling in the striatum in people with schizophrenia has been seen in fMRI studies, with both reduced and increased activation in response to unexpected rewards reported (Gradin et al., 2011; Morris et al., 2012; Murray et al., 2008). One study found a specific reduction in positive prediction error (more reward than expected) signalling in the striatum whilst negative prediction error (less reward than expected) was found to be intact (Waltz et al., 2009). In contrast, Dowd and Barch (2012) found intact positive prediction error responses in people with schizophrenia, although these were seen in cortical regions and not the striatum. In sum, it seems that prediction error signalling is abnormal in schizophrenia and may contribute to anticipatory pleasure deficits although the direction and magnitude of the differences varies across studies.

These findings raised the important question of the role of dopamine in anticipatory pleasure, and therefore the potential effects of antipsychotic medication. In un-medicated people with schizophrenia reduced ventral striatum activity during anticipation of reward has been reported (Esslinger et al., 2012; Juckel et al., 2006b). One study which compared drug-free patients and those being treated with neuroleptics found that dopamine D2/D3 receptor availability was negatively correlated with affective flattening as measured by the SANS but not anhedonia/social withdrawal (Heinz et al., 1998). This finding was replicated (Schmidt et al., 2001) and the authors suggested that patients who experience dopaminergic dysfunction are able to experience pleasure but may struggle to respond to external stimuli which prompt them to seek it out. This supports the finding that antipsychotic medication may have a bigger impact on anticipatory rather than consummatory pleasure. It appears that reduced activation of the ventral striatum in response to rewarding cues may be more pronounced in those people taking typical antipsychotics but not those taking atypical antipsychotics; with this effect being correlated with negative symptom severity in those taking typical antipsychotics only (Juckel et al., 2006a; Kirsch et al., 2007; Schlagenhauf et al., 2008; Simon et al., 2010; Walter et al., 2009). The limited behavioural studies have consistently reported no association between medication type/dosage and anticipatory pleasure (Choi et al., 2013; Trémeau et al., 2010). This is an important area which requires clarification as it is possible that the effect of medication may not translate into behavioural changes. Alternatively, it may be that the measures used in these studies (most commonly the Chapman Scales) are not detecting changes at the behavioural level. However, the small sample sizes in the neuroimaging studies make it unlikely such a small association has been detected. The vast majority of studies considered in this review include individuals with chronic schizophrenia, who have been prescribed high levels of antipsychotic medication. The association found here between neuroleptics and abnormal anticipation may therefore not generalise to all individuals with this diagnosis, particularly not those experiencing their first episode

### 3.6. Approach motivation/behaviour

The final stage in the cycle is the motivation and behaviours which, depending on the outcome, may lead to the activity occurring again. Only three studies were retrieved which investigated the link between these factors and anhedonia. Two studies used self-report measures of motivation—the Motivational Trait Questionnaire (MTQ) (Barch et al., 2008) and motivation ratings using Likert scales in relation to a task (Trémeau et al., 2014). There were no differences between groups on any subscales on the MTQ (except lower anxiety-linked motivation in people with schizophrenia) or the ratings given during the Tremeau study. The final study used an experimental task in which participants had to press a button repeatedly to avoid or view a picture they had previously rated (Heerey and Gold, 2007). Although the button press frequency was comparable between groups, people with schizophrenia failed to discriminate between pleasant and unpleasant images as consistently as controls. Individuals with schizophrenia did not, as expected, press the button less for images they had previously found unpleasant,

**Table 3**
A table reporting correlations between measures of executive functions and anhedonia scores.

| Study | Task | Areas of cognition mean (SD) | Measure of anhedonia mean (SD) | Sample | Results |
|---|---|---|---|---|---|
| Impaired decision making in schizophrenia spectrum and orbitofrontal cortex lesion patients (Larquet et al., 2010). | WAIS III<br>The Stroop test, the trail making test, verbal fluency test, Wisconsin Card Sorting Task (WCST). | IQ = 80.6 (16.2)<br>Executive Functions<br>Stroop_a = 73.8 (15.7)<br>Stroop_b = 49.42 (13.9)<br>Stroop_c = 140.45 (39.7)<br>Trail making test_a = 48.3 (15.8)<br>Trail making test_b = 130.7 (74.7)<br>Fluency_letters = 17.19 (5.1)<br>Fluency_animals = 24 (5.4)<br>WCST = 5.14 (1.9)<br>WCST_errors = 3.2 (3.98) | Chapman scales<br>Social anhedonia = 16 (6.3)<br>Physical anhedonia = 20.4 (9.4) | 21 schizophrenia spectrum patients<br>10 orbitofrontal cortex lesion patients and 20 healthy controls. | *No significant correlations* between WCST, Stroop, trial making or fluency test and anhedonia in schizophrenia spectrum patients<br>($ps > 1$)<br>No analysis of these relationships was conducted in the control group. |
| Deficits in positive reinforcement learning and uncertainty-driven exploration are associated with distinct aspects of negative symptoms in schizophrenia (Strauss et al., 2011a) | Go NoGo Task | Reinforcement learning<br>Data reported in graph format.<br>Uncertainty driven exploration<br>High negative symptom group = 1187 (1561)<br>Low negative symptom group = 1323 (1678) | SANS<br>Median split = 38.39. | 51 patients with schizophrenia, 39 age-matched healthy controls. | Intact NoGo but *impaired Go learning* in schizophrenia spectrum ($p = 0.003$).<br>High negative symptom patients had a *greater impairment in Go learning* with slower speeding up of RTs compared to the other groups ($p = 0.01$).<br>*Performance did not correlate with SANS scores*.<br>Reduced uncertainty driven exploration in the task was *significantly correlated* with anhedonia/asociality only — ($p < 0.05$).<br>No measure of anhedonia in the control group. |
| The emotional paradox: dissociation between explicit and implicit processing of emotional prosody in schizophrenia (Roux et al., 2010). | Emotional stroop task. | Executive functions.<br>Accuracy: congruent = 0.849 (0.378)<br>Incongruent = 0.828 (0.358)<br>Reaction time (ms): congruent = 1308.9 (488.9)<br>Incongruent = 1338.0 (517.4) | PANSS negative subscale 24 (5.1)<br>Chapman scales<br>Physical anhedonia = 17.9 (9.0)<br>Social anhedonia = 15.2 (5.8) | 21 schizophrenia spectrum patients<br>21 healthy controls. | Higher reaction times on stroop task *associated at trend level* with social anhedonia ($p = .052$) but *not* physical anhedonia ($p = 0.6$).<br>Correlational analysis not performed in control group. |
| The emotional Stroop task: a comparison between schizophrenic subjects and controls (Demily et al., 2010). | Emotional stroop task | Executive functions<br>Reaction times:<br>Positive words = 1134 (168)<br>Negative words = 1132 (169)<br>Neutral words = 1048 (158)<br>Symbols = 944 (133)<br>Four stimuli = 1077 (158)<br>Number of errors = 3.4%. | PANSS negative subscale 21.17 (3.11)<br>Chapman scales<br>Physical anhedonia = 22 (7.9)<br>Social anhedonia = 16.1 (4.3) | 21 patients with schizophrenia spectrum disorders<br>20 healthy controls. | *No significant correlations* between Stroop task and social anhedonia ($ps > 0.69$) or physical anhedonia ($ps > 0.55$) in schizophrenia.<br>No correlational analyses conducted for controls. |
| Executive/attentional performance and measures of schizotypy in patients with schizophrenia spectrum and in their nonpsychotic first-degree relatives (Laurent et al., 2000). | Degraded Stimulus-Continuous Performance Test.<br>Forced-choice span of apprehension test.<br>Digit symbol substitution test<br>Trail making A+B<br>Verbal fluency<br>Stroop task<br>WCST | Attention<br>DS-CPT perceptual sensitivity =<br>SZ: 3.11 (0.83)<br>HC: 3.80 (0.91)<br>Perceptual evidence before decision=<br>SZ: 1.15 (1.13)<br>HC: 0.72 (1.00)<br>Reaction time (ms) = SZ: 557 (82)<br>HC: 477 (60)<br>SPAN (% correct):<br>3-letter = SZ: 96.6 (4.8)<br>HC: 96.5 (3.5)<br>12-letter = SZ: 78.8 (8.4)<br>HC: 81.7 (7.4) | PANSS negative subscale 23.9 (7.3)<br>SZ<br>Chapman Scales<br>Physical anhedonia = 20.5 (8.7)<br>Social anhedonia = 13.7 (5.3)<br>Controls<br>Chapman scales<br>Physical anhedonia = 11.8 (6.3)<br>Social anhedonia = 6.5 (3.2) | 23 schizophrenia spectrum outpatients.<br>At-risk group of 25 parents and 22 siblings.<br>34 healthy controls. | *No significant correlations* between any of these cognitive measures and the Chapman scales in the patient group ($ps > .05$) |

*(continued on next page)*

**Table 3** (*continued*)

| Study | Task | Areas of cognition mean (SD) | Measure of anhedonia mean (SD) | Sample | Results |
|---|---|---|---|---|---|
| | | Reaction time (ms):<br>3-letter = SZ: 786 (165)<br>HC: 655 (89)<br>12-letter = SZ: 1101 (266)<br>HC: 887 (171)<br>Speed of processing.<br>SZ: 42.7 (11.1)<br>HC: 57.7 (11.1)<br>Executive functions<br>Trail making A (s) = SZ: 3.62 (0.38)<br>HC: 3.54 (0.40)<br>Trail Making B (s) = SZ: 4.63 (0.49)<br>HC: 4.22 (0.36)<br>Verbal fluency letters = SZ: 54.3 (17.6)<br>HC: 72.5 (16.8)<br>Verbal fluency categories = SZ: 40.6 (10.1)<br>HC: 55.9 (9.7)<br>Stroop (interference) = SZ: 1.98 (6.5)<br>HC: 5.2 (7.3)<br>WCST preservative errors = SZ: 27.3 (26.0)<br>HC: 17 (1.8)<br>WCST categories achieved = SZ: 3.13 (2.34)<br>HC: 4.63 (1.67) | | | |
| Relations between neuropsychological vulnerability markers and negative symptoms in schizophrenia (Suslow et al., 1998). | Visual backward masking task.<br>Span of apprehension test.<br>Degraded stimulus-continuous performance test<br>WCST. | Information processing.<br>Backward masking (hit rate):<br>No information mask-ISI 43 ms = 73.9 (18.6)<br>ISI 114 ms = 85.0 (13.4)<br>Letter mask-ISI 43 ms = 46.3 (15.3)<br>ISI 114 ms = 78.3 (16.9)<br>Attention<br>SPAN (identifications) 12-letter array = 47.8 (6.4)<br>DS-CPT false alarm rate = 0.08 (0.07)<br>sensitivity = 0.89 (0.08)<br>Executive functions.<br>Preservative errors = 10.2 (11.3)<br>Non-preservative errors = 27.2 (21.4) | SANS<br>Anhedonia-asociality = 6.8 (4.1) | 31 patients with predominantly negative symptoms. | Anhedonia-asociality *significantly negatively correlated* with preservative errors on WCST when medication is controlled for ($r = -0.48$, $p = <.001$).<br>*No correlations* with the other tasks. |
| Affective and social-behavioural correlates of physical and social anhedonia in schizophrenia (Blanchard et al., 1994). | WAIS-R | IQ<br>Mean (SD) not reported. | Chapman scales<br>Physical anhedonia = 16.92 (8.70)<br>Social anhedonia = 15.15 (6.69)<br>SANS anhedonia-asociality = 2.43 (1.19) | 26 sz patients, 9 schizoaffective disorder patients, 9 bipolar patients | *No significant correlations* between WAIS-R Information or vocabulary sub-tests and either Physical or social anhedonia in the schizophrenia spectrum group ($rs < .21$, $ps > .05$). |
| Conditional associative learning in drug-free schizophrenic patients (Kemali et al., 1987). | Spatial and non-spatial conditional associative learning tasks | Spatial (SCAL) and Non-Spatial (NSCAL) Conditional Associative Learning Ability<br>SCAL<br>Total errors = 131.2 (59.3)<br>Total time (s) = 546.5 (202.6)<br>Mean time (s) = 37 (13)<br>Correct trials (%) = 5.3 (10.1)<br>Correct items (%) = 43.9 (21.4)<br>Learned associations = 3.4 (1.9)<br>NSCAL<br>Total errors = 119.4 (70.1)<br>Total time (s) = 609.4 (230.6)<br>Mean time (s) = 43.6 (13.5)<br>Correct trials (%) = 13.5 (16.6)<br>Correct items (%) = 50.4 (19.3)<br>Learned associations = 3.9 (2.0) | SANS<br>Mean (SD) not reported. | 21 male drug-free schizophrenia spectrum patients, 19 healthy controls. | *No correlation* between spatial conditioning learning and SANS.<br>Number of errors, reaction time and number of learned associations in the non-spatial learning task *negatively correlated* with SANS anhedonia subscales ($rs = -0.5$, $ps < .05$).<br>No measure of anhedonia in the control group. |

| | | | | | |
|---|---|---|---|---|---|
| Intrinsic motivation in schizophrenia: Relationships to cognitive function, depression, anxiety, and personality. Barch et al., 2008 | WAIS III<br>AX-continuous Performance task<br>2-back version of the n back task | IQ<br>WAIS-III Vocab = SZ: 8.5 (3.7)<br>HC: 10.4 (3.6)<br>WAIS-III matrix reasoning = SZ: 9.4 (3.3)<br>HC: 11.9 (3.9)<br>Attention-context processing.<br>Short-delay performance:<br>AX errors = SZ: 0.06 (0.08)<br>HC: 0.01 (0.02)<br>AY errors = SZ: 0.13 (0.15)<br>HC: 0.09 (0.02)<br>BX errors = SZ: 0.24 (0.31)<br>HC: 0.09 (0.17)<br>BY errors = SZ: 0.04 (0.11)<br>HC: 0.03 (0.14)<br>Context sensitivity = SZ: 2.5 (1.3)<br>HC: 3.4 (0.6)<br>Long-delay performance:<br>AX errors = SZ: 0.21 (0.24)<br>HC: 0.13 (0.25)<br>AY errors = SZ: 0.09 (0.16)<br>HC: 0.12 (0.18)<br>BX errors = SZ: 0.25 (0.34)<br>HC: 0.11 (0.18)<br>BY errors = SZ: 0.4 (0.11)<br>HC: 0.4 (0.17)<br>Context sensitivity = SZ: 1.8 (1.2)<br>HC: 2.6 (1.4)<br>Working memory<br>0-back accuracy = SZ: 0.94 (0.10)<br>HC: 0.95 (0.09)<br>1-back accuracy = SZ: 0.88 (0.09)<br>HC: 0.93 (0.08)<br>2-back accuracy = SZ: 0.79 (0.10)<br>HC: 0.87 (0.10) | SANS<br>Anhedonia-asociality = 2.6 (1.3)<br>SZ<br>Chapman scales<br>Physical anhedonia = 17.0 (5.7)<br>Social anhedonia = 14.7 (4.8)<br>HC<br>Chapman scales<br>Physical anhedonia = 11.7 (4.5)<br>Social anhedonia = 11.5 (4.8) | 66 sz patients, 44 healthy controls. | *No significant associations* between any motivation measures and any of the measures of cognition except for 'motivation related to anxiety' which was *negatively correlated* with AX-CPT performance ($r = -.36$, $p < .05$).<br>All three measures of cognition (WAIS-II, AX-CPT, 2-back) *associated with motivation* measures in the control group- personal mastery, competitive excellence and 'motivation related to anxiety'.<br>*No results reported* for anhedonia and cognition. |
| Attentional abilities and measures of schizotypy: their variation and covariation in schizophrenic patients, their siblings, and normal control subjects (Franke et al., 1994). | Continuous performance test - Identical Pairs. | Attention<br>Fast numbers (no distraction):<br>Sensitivity=<br>SZ: 1.25 (0.68)<br>HR: 1.38 (0.68)<br>HC: 1.61 (0.69)<br>Response criterion = SZ: 0.04 (0.70)<br>HR: −0.24 (0.47)<br>HC: −0.33 (0.68)<br>Random trials = SZ: 2.76 (2.77)<br>HR: 1.96 (2.44)<br>HC: 1.67 (2.61)<br>Fast shapes (no distraction):<br>Sensitivity = SZ: 1.18 (0.62)<br>HR: 1.56 (0.68)<br>HC: 1.98 (0.75)<br>Response criterion = SZ: 0.32 (0.57)<br>HR: 0.25 (0.50)<br>HC: −0.15 (1.01)<br>Random trials = SZ: 4.40 (2.58)<br>HR: 3.24 (2.73) | Chapman scales<br>Physical anhedonia=<br>SZ: 23.3 (11.2)<br>Siblings (HR): 15.7 (3.4)<br>HC: 11.8 (2.9) | 35 sz patients, 26 healthy siblings and 35 controls. | Performance on CPT *did not correlate* significantly with anhedonia scores in the schizophrenia spectrum, healthy control or high-risk siblings group. |

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**Table 3** (*continued*)

| Study | Task | Areas of cognition mean (SD) | Measure of anhedonia mean (SD) | Sample | Results |
|---|---|---|---|---|---|
| | | HC: 2.24 (2.68)<br>Fast numbers (distraction):<br>Sensitivity = SZ: 0.95 (0.43)<br>HR: 1.02 (0.60)<br>HC: 1.36 (0.69)<br>Response criterion = SZ: 0.26 (0.58)<br>HR: 0.12 (0.65)<br>HC: −1.16 (0.43)<br>Random trials = SZ: 3.91 (2.75)<br>HR: 3.83 (2.76)<br>HC: 3.80 (2.49)<br>Fast shapes (distraction):<br>Sensitivity = SZ: 1.02 (0.64)<br>HR: 1.81 (0.94)<br>HC: 2.23 (1.03)<br>Response criterion = SZ: 0.28 (0.58)<br>HR: −0.04 (0.83)<br>HC: 0.06 (1.20)<br>Random trials = SZ: 4.35 (2.74)<br>HR: 3.13 (2.80)<br>HC: 2.48 (2.63)<br>Slow numbers (no distraction):<br>Sensitivity = SZ: 1.36 (0.66)<br>HR: 1.85 (0.77)<br>HC: 2.33 (1.01)<br>Response criterion = SZ: 0.08 (0.92)<br>HR: −0.19 (1.00)<br>HC: −0.30 (1.02)<br>Random trials = SZ: 2.57 (2.73)<br>HR: 1.21 (2.32)<br>HC: 1.02 (2.09)<br>Slow shapes (no distraction):<br>Sensitivity = SZ: 1.66 (1.03)<br>HR: 2.34 (1.10)<br>HC: 2.99 (0.93)<br>Response criterion = SZ: 0.25 (1.20)<br>HR: 0.37 (1.20)<br>HC: −0.05 (1.30)<br>Random trials = SZ: 3.40 (2.92)<br>HR: 1.97 (2.62)<br>HC: 1.27 (2.20) | | | |
| Probabilistic reversal learning impairments in schizophrenia: further evidence of orbitofrontal dysfunction (Waltz and Gold, 2007). | Probabilistic reversal learning task | Rapid reinforcement learning<br>Reported in graph form. | SANS<br>33.18 (16.82) | 34 patients with schizophrenia, 26 controls. | Patients show *impairment in reversal learning* — fewer successful reversals ($p = 0.008$). *No significant association* of reversal learning with anhedonia subscale of SANS ($P = 0.42$). *Trend* with affective blunting (0.06).<br>No measure of anhedonia in the control group. |
| Influence of emotional processing on working memory in schizophrenia spectrum (Becerril & Barch, 2011). | 2-back working memory task with emotional faces | Accuracy and reaction times during task-reported in graph form. | Scores per item.<br>Chapman Scales<br>Social Anhedonia<br>SZ: 4.92 (2.1)<br>HC: 2.35 (2.2)<br>Physical Anhedonia<br>SZ: 6.76 (4.17)<br>HC: 3.71 (3.1)<br>SANS<br>1.84 (0.95) | 38 patients with schizophrenia, 32 controls. | *No significant associations* in either group between any measure of anhedonia and accuracy or reaction times on the 2-back working memory task. |

| | | | | | |
|---|---|---|---|---|---|
| Reward processing in schizophrenia: a deficit in the representation of value (Gold et al., 2008). | Speeded button pressing for pictures of different valence.<br>Delayed discounting tasks.<br>Wisconsin Card-Sorting Task<br>Probabilistic Reversal Learning Task<br>Frank Probabilistic Selection Paradigm | Reported in graph form. | SANS | Summary results across 8 studies. | Correlations consistently observed below .3–.4 and non-significant with all these tasks.<br>No anhedonia measure in the control group. |
| Cognitive correlates of schizophrenia spectrum signs and symptoms: II. Emotional disturbances.<br>Berenbaum et al. (2008) | Verbal and design fluency tasks. Working memory tasks- reading span and AX-CPT.<br>Digit span forward subtest of WAIS-R as measure of attention.<br>Lateralised motor performance task. | Not reported | SANS<br>Anhedonia<br>3 (0.5) | 47 people with schizophrenia spectrum disorder. | *No association* between anhedonia and fluency, working memory, digit span or episodic memory tasks.<br>Anhedonia *negatively correlated* with lateralized task performance. |
| The relationship between negative symptoms and neuropsychological performance.<br>Hammer et al. (1995) | WAIS-R verbal and performance scales<br>The finger tapping test<br>Trail making test (A and B)<br>WCST<br>Word fluency<br>Rey Auditory Verbal Learning Test (RAVLT)—verbal memory.<br>Benton Visual Retention Test Form (BVRT)—visual memory. | Not reported | SANS | 65 people with schizophrenia. | *Anhedonia* subscale of the SANS significantly associated with word fluency ($r = -0.27$), perseverative errors on the WCST (0.30) and reaction times on the Trail Making Test (A) (0.27). |
| Anhedonia and the experience of emotion in individuals with schizophrenia (Burbridge and Barch, 2007). | California Verbal Learning Test (CVLT)<br>Digit span backward | CVLT-2 short delay free recall<br>SZ: 7.7 (3.0)<br>HC: 11.6 (3.2)<br>Digit span backward<br>SZ: 6.4 (2.3)<br>HC: 7.5 (2.3) | Chapman scales<br>Social anhedonia<br>SZ: 38.2 (21.2)<br>HC: 20.9 (15.4)<br>Physical anhedonia<br>SZ: 27.4 (16.7)<br>HC: 15.0 (9.5) | 49 people with schizophrenia, 47 controls. | *No association* between Chapman scale scores and cognitive measures in either group. |
| Impaired modulation of attention and emotion in schizophrenia (Dichter et al., 2010). | Forced-choice visual oddball task<br>fMRI | Accuracy mean (SE)<br>Aversives<br>0.88 (0.027)<br>Circles<br>0.68 (0.059)<br>Neutrals<br>0.90 (0.025)<br>Reaction times mean (SE)<br>Aversives<br>674.54 (62.08)<br>Circles<br>605.57 (21.56)<br>Neutrals<br>614.71 (37.60) | SANS<br>Anhedonia-asociality<br>2.17 (1.80) | 16 individuals with schizophrenia spectrum disorder,<br>13 controls. | *No association* between behavioural scores on the task and any SANS subscales.<br>No measure of anhedonia in the control group. |

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**Table 3** (*continued*)

| Study | Task | Areas of cognition mean (SD) | Measure of anhedonia mean (SD) | Sample | Results |
|---|---|---|---|---|---|
| Correlations between clinical symptoms, working memory functions and structural brain abnormalities in men with schizophrenia (Szendi et al., 2006). | Digit span (forwards and backwards)<br>Nonword repetition test<br>Corsi blocks<br>Visual patterns test<br>WCST<br>Towers of Hanoi<br>Letter and Category Fluency Task | WCST categories<br>4 (2.35)<br>Perseverative errors %<br>16.23 (8.32)<br>Conceptual level responses %<br>52.31 (27.21)<br>Failure to maintain set<br>0.54 (0.97)<br>Digit span<br>Forward<br>5.77 (1.17)<br>Backward<br>4.23 (1.01)<br>Nonword repetition test<br>6.23 (1.09)<br>Corsi blocks forward<br>6.46 (0.88)<br>Corsi blocks backward<br>5.85 (1.35)<br>Visual patterns test<br>7.54 (1.81)<br>Tower of Hanoi (steps)<br>11 (5.31)<br>Letter fluency (words)<br>8.56 (2.41)<br>Letter fluency (errors)<br>1.15 (0.99)<br>Category fluency (words)<br>14.49 (3.26)<br>Category fluency (errors)<br>0.91 (0.82) | SANS<br>Anhedonia<br>1.6 (1.2) | 13 males with schizophrenia, 13 male controls. | *Anhedonia scores correlated with* Corsi backwards task scores ($r = -.056$) and performance on The Tower of Hanoi task ($-0.62$).<br>No measure of anhedonia in the control group. |
| Anhedonia in prolonged schizophrenia spectrum patients with relatively lower vs. higher levels of depression disorders: Associations with deficits in social cognition and metacognition (Buck et al., 2014). | Wisconsin Card Sorting Task | WCST Number of categories correct<br>High depression/high anhedonia: 3.65 (2.11)<br>Low depression/low anhedonia: 3.81 (1.99)<br>Low depression/high anhedonia: 2.95 (2.33) | PANSS Negative<br>High depression/high anhedonia: 20.48 (5.36)<br>Low depression/low anhedonia: 16.85 (4.43)<br>Low depression/high anhedonia: 21.15 (4.91) | 163 SCZ; 52 high depression/high anhedonia, 52 low depression/low anhedonia, 59 low depression/high anhedonia. | *No difference* between groups with differing levels of anhedonia and scores on the WCST. |
| Deficits in emotion based decision-making in schizophrenia; a new insight based on the Iowa Gambling Task (Matsuzawa et al., 2015). | Iowa gambling task | Reported in graph form. | SANS total<br>76.1 (13.9) | 61 people with schizophrenia and 50 age- and sex-matched controls. | Card choices (advantageous/disadvantageous) *correlate with* SANS anhedonia-asociality.<br>No measure of anhedonia in the control group. |

or increase presses for images they had previously found pleasant. These findings describe a deficit in linking goals or preferences with actions. Some support for this hypothesis comes from an experience sampling study which reported that individuals with schizophrenia completed fewer goal-directed activities than controls (Gard et al., 2007). A recent ESM study extended this by asking participants and independent raters to rate the effort required for the goals set by the participants in everyday life (Gard et al., 2014). People with schizophrenia were more inaccurate than controls compared to the independent raters, and set fewer effortful goals. This finding was not replicated in an effort-discounting experimental task which showed no deficit in people with schizophrenia compared to controls and no link with negative symptoms (Docx et al., 2015). There is little evidence to suggest that motivation is consistently low in schizophrenia or that there is a difficulty identifying goals or desired rewards. These studies suggest that the problem is in generating and directing the required effort and actions towards these goals or rewards. The link between motivation and action would be an important target for a therapy.

## 4. Discussion

### 4.1. Potential therapeutic targets

The most consistent finding in the reviewed literature is that consummatory pleasure is intact in people with schizophrenia. Emotional memory emerges as an important deficit in people with schizophrenia with a strong evidence base. Even though the experimental data is equivocal there is support for deficits in executive functions and building/maintaining representations contributing to anhedonia in the neuroimaging literature using reward-based tasks. Additional findings from an experimental task are in line with a deficit in maintaining representations over time.

Although there is a strong assumption that neuropsychological task performance is linked to anhedonia there was no evidence in the literature for this assumption. It may be that an emotional component in tasks assessing executive functions is required.

There is preliminary self-report evidence for a specific anticipatory deficit in the context of intact consummatory pleasure in people with schizophrenia which requires replication in an experimental context and daily life. There is also some indication that individuals with schizophrenia may have difficulty translating motivation into actions towards desired goals.

### 4.2. Limitations of the current evidence base

In recent years the field has moved from assuming a unitary emotional deficit to considering the multiple components involved in experiencing and anticipating pleasure separately. This approach more accurately reflects both intact pleasure processes and some areas where people with schizophrenia differ from the general population. Experimental tasks have focused on consummatory pleasure, a now well-established intact component, and neglected other processes. Important avenues of future research are experimental assessments of anticipatory pleasure, representation maintenance and motivation which would progress our understanding of these processes in people with schizophrenia and the control population.

There has been extensive use of self-report measures that rely heavily on retrospective emotional memory. This is often impaired in individuals with schizophrenia and future research should focus on using methodologies which avoid such a heavy reliance (Herbener, 2008). Experience sampling methodology has shown promise in this field and allows a direct measurement of activity levels and pleasure experienced during everyday life.

It is important to highlight the large number of null findings in this review, particularly regarding the links between memory, executive functions and self-reported anhedonia. This may be due to the small sample sizes included in the large majority of the studies considered (i.e. average sample size = 40). The majority of studies may therefore have been under-powered to detect a small-moderate correlation or effect size. A small-moderate association may be expected if the contribution of executive functions and emotional memory to anticipatory pleasure is moderated by other factors in the TEP model. The replicability of the empirical evidence presented in this review is limited by the sample sizes of the studies included and investigations should be conducted with larger samples to test these hypotheses in the future.

The vast majority of studies used measures of anhedonia similar to the BPRS and SANS which, as discussed previously, are limited in their ability to accurately assess anhedonia in people with schizophrenia. Other studies used the Chapman scales which are designed to assess anhedonia the general population. The use of these older scales may also contribute to the large amount of null findings in the field when examining relationships with anhedonia as they are not specific measures of anticipatory or consummatory pleasure. The use of newer, more specific, measures would increase the methodological reliability of studies assessing the TEP model.

### 4.3. Strengths and limitations

This review met the aim of identifying evidence-based therapeutic targets among the constructs proposed in the TEP model and used stringent PRISMA guidance. A publication bias in the literature is unlikely given the many studies reporting null findings as well as positive findings for any construct contributing to the experience of anhedonia in people with schizophrenia. Our conclusions are limited by the measures of anhedonia used in the majority of studies, which are non-specific and do not reflect current thinking in this area. Future studies should prioritise more specific measures such as the CAINS and BNSS (Horan et al., 2011; Kirkpatrick et al., 2011). We did not assess the impact of co-morbid diagnoses such as substance abuse on emotional experience. Although studies conducted in many countries including China, Japan, Hong Kong, Germany, France, The Netherlands and Spain are reviewed, we may have introduced some bias by excluding those not written in English, although we do not consider this likely.

### 4.4. Clinical implications

#### 4.4.1. Emotional memory

If the evidence continues to support a specific anticipatory pleasure deficit linked to emotional memory in people with schizophrenia then psychological therapies could start to target this specific problem. Treatment studies also allow further tests of the hypotheses set out in the TEPS model. For example an effect on activity as the result of enhancing anticipatory pleasure may be mediated by motivation. Two pilot studies using Anticipatory Pleasure Skills Training and Broad Minded Affective Coping (Favrod et al., 2010; Tarrier, 2010) report an improvement in self-reported anhedonia after treatment but do have very small sample sizes ($n < 10$). Both interventions encourage the individual to visualise a previous similar activity in a relaxed state. They enhance the multimodality of the anticipation by asking participants to do this using as many senses as possible. Focusing on the details of a specific event limits over-general memory (recalling a general impression of an activity rather than a specific event) which may affect the ability to anticipate pleasure accurately. These therapies build on the individual's intact experience of pleasure in the moment to give them fuller experiences of remembering that pleasure when anticipating activities in the future. An advantage of these therapies is that they can easily be adapted into short training sessions which could be administered, in addition to, or as part of, a comprehensive cognitive and behavioural treatment strategy. Cognitive Remediation Therapy (CRT) (Wykes et al., 2007) targets memory processes using task-based training and could also be adapted to enhance emotional memory specifically. Adding emotional components to memory tasks or using videos of events could help the individual to strengthen the links between their emotions and memories of an event.

*4.4.2. Executive functions: creating and maintaining representations*

If, as suspected, executive functions contribute to anhedonia, then Cognitive Remediation Therapy could have a beneficial effect. Available cognitive training to enhance executive functions could be augmented to specifically target anticipating pleasure from future activities e.g. predicting the details of future events and incorporating emotions. Further research to understand the type of cognitive training that could improve reward anticipation is needed. A recent study demonstrated that CRT can improve reward and punishment sensitivity in people with schizophrenia (Cella et al., 2013). Changes in this parameter may have an impact on the anticipatory pleasure experienced and, in turn, reduce anhedonia. At the very least the current data on cognitive remediation could be explored for links between improved cognitive function and anhedonia which can lead to further therapy developments. The addition of specific scales in future trials may also allow an investigation of these links and the development of models of therapeutic action. For instance reward experienced in therapy might generalise within therapy to faster learning and also to increased motivation to carry out tasks in everyday life. The pleasure associated with these tasks may increase the likelihood that they are repeated because they build an evidence base for the individual that they can use to drive future behaviour.

*4.4.3. Approach motivation/behaviours*

The literature suggests that the low levels of activity reported by individuals with schizophrenia could be the result of a difficulty in translating motivation into pleasurable activities. This may be the result of a deficit in planning ability. This is already a target of CRT but the therapy could be adapted towards enhancing this further and for leisure as well as functional activities.

Techniques from Cognitive Behavioural Therapy for Psychosis (CBTp) (Turkington et al., 2006) may improve the process of translating motivation into action. CBTp has a good evidence base, and although it is rare for a study to report anhedonia as an outcome measure, a few studies report a general improvement in negative symptoms (but sample sizes are small) (Rathod et al., 2008). Future research reporting the effectiveness of adapted CBTp for negative symptoms, such as that developed by Grant et al. (2012) which reported an improvement in avolition but not anhedonia, would greatly facilitate the development of therapy. Therapists using CBTp identify personally relevant goals and use these to support the client's motivation in therapy. Imagery based techniques can enhance the vividness and specificity of the goal and link it to previous similar events. Asking individuals to record their activities and their enjoyment of them in a pleasure diary may also be relevant. Deficits in anticipatory pleasure have also been described in depression (Sherdell et al., 2012) and a mood diary has been used effectively in Cognitive Therapy of Depression (Beck, 1979). A pleasure diary could be used to challenge the belief that the individual experiences low pleasure and highlights the activities they do find enjoyable. An imaginary diary of their desired activity schedule could also be compared to their real diary to highlight discrepancies and identify behavioural targets. Explicitly focussing on the cognitive dissonance between forecasted and experienced pleasure and working through this with the individual could prove beneficial. Mobile technology could be adapted to enhance therapy by providing a more interactive way of recording emotions and activities. Such a tool could also provide regular support and encouragement using real-time information about enjoyable activities.

In conclusion this systematic review identified several promising therapeutic targets for emotional and motivational deficits in people with schizophrenia. The evidence suggests that current therapeutic practices including CRT, CBTp, mobile technology and imagery/visualisation could be adapted to effectively target the three constructs with the strongest empirical support (emotional memory, executive functions and approach motivation/behaviours) that may contribute to the lack of pleasure reported by people with schizophrenia.

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**Contributors**

Author CE managed the systematic literature search. All authors reviewed the included papers and contributed to the writing of the review.

**Conflict of interest**

The authors report no conflicts of interest.

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## Appendix 1

| Reference | sample size | Negative symptom measure | Method | Findings | TEP model construct |
|---|---|---|---|---|---|
| Barch et al. (2008) | 66 SCZ or schizoaffective disorder/44 healthy controls. | SANS + Chapman Scales | Motivational Trait Questionnaire. WAIS III Matrix Reasoning, WAIS III Vocabulary, 2-back version of the n-back task, AX version of the Continuous Performance Task. | No association found with motivational traits and anhedonia. Results for cognition and anhedonia not reported. | Approach motivation and behaviours |
| Barch et al. (2014) | 59 people with schizophrenia/39 matched controls. | SANS, Chapman Scales, SHAPS, TEPS. | Effort-expenditure for rewards task | Individuals with schizophrenia show lower effort expenditure with increasing reward or probability than controls. Fewer difficult choices associated with more severe negative symptoms and worse functioning. | Approach motivation and behaviours |
| Becerril and Barch (2011) | 38 SCZ/32 healthy controls | SANS Chapman Scales | 2-Back working memory task with emotional faces. fMRI | Social anhedonia associated with diminished responses to emotional stimuli and increased dorsolateral prefrontal cortex activity. | Executive functions and activation/maintenance of representation |
| Berenbaum et al. (2008) | 47 SCZ | SANS | Verbal and design fluency tasks. Working memory tasks—reading | Anhedonia did not correlate with the measures of fluency, working | Executive functions and activation/maintenance |

**Appendix 1** (*continued*)

| Reference | sample size | Negative symptom measure | Method | Findings | TEP model construct |
|---|---|---|---|---|---|
| | | | span and AX-CPT. Digits forward subtest of WAIS-R as measure attention. Lateralised motor performance task. | memory or attention. Anhedonia did correlate with lateralised task performance. | of representation |
| Berlin et al. (1998) | 20 SCZ/20 major depression/20 healthy controls. | Chapman Scales | Hedonic responses to sucrose. | Hedonic response to sucrose was inversely correlated with physical anhedonia. | Consummatory pleasure |
| Bodapati and Herbener (2014) | 38 SCZ/53 matched healthy controls | PANSS | In the moment emotional responses to social and non-social stimuli—IAPS images. | Control more aroused by social vs. non-social images—not in SCZ group. Negative symptom severity predicted lower arousal responses to unpleasant stimuli. | Consummatory pleasure |
| Brebion et al. (1999) | 33 SCZ/40 healthy controls. | SANS | Free recall and recognition memory tasks. | Fewer errors associated with anhedonia in SCZ group. | Memory |
| Brebion et al. (2005) | 41 SCZ/43 healthy controls. | SANS | Verbal recognition task. | Anhedonia correlated with a reduced response bias. | Memory |
| Brebion et al. (2007a) | 41 SCZ/43 healthy controls. | SANS | Temporal context memory task. | Anhedonia associated with significantly fewer errors. | Memory |
| Brebion et al. (2007b) | 41 SCZ | SANS | Visual memory task—recognition and spatial memory. | Anhedonia was associated with response bias, in the opposite direction from hallucinations (increased accuracy). | Memory |
| Brébion et al., 2010 | 41 SCZ/43 healthy controls. | SANS | Production of atypical category exemplars. | Anhedonia significantly inversely correlated with typicality score. | Memory |
| Brebion et al. (2012) | 41 SCZ/43 healthy controls. | SANS | Source memory, recall and recognition tasks for words and pictures. | Verbal, visual and source memory errors inversely correlated with anhedonia scores. | Memory |
| Buck and Lysaker (2013) | 163 SCZ; 52 high depression/high anhedonia, 52 low depression/low anhedonia, 59 low depression/high anhedonia. | PANSS | Wisconsin Card Sorting Task, Metacognition questionnaire, Bell–Lysaker Emotional Recognition Task. | No difference between depression/anhedonia groups in number of categories correct on the WCST. High anhedonia/low depression group had worse metacognition and social cognition scores. | Executive functions and activation/maintenance of representation |
| Burbridge and Barch (2007) | 49 SCZ/47 healthy controls. | Chapman Scales | Ratings of emotional stimuli and tests of working and episodic memory. | Limited evidence for a link between working memory and physical anhedonia. No other associations. No difference in emotional ratings between SCZ and controls. | Executive functions and activation/maintenance of representation |
| Chan et al. (2012) | | | | | Anticipatory pleasure |
| Choi et al (2013) | 15 SCZ/17 controls. | Chapman Scales, PANSS. | Participants rated the pleasantness of both a preview and viewing stage of a film clip. fMRI. | There was no difference between groups in anticipatory or consummatory pleasure ratings. There was reduced activation in the anterior cingulate cortex during the preview phase in the SZ group. | Anticipatory pleasure |
| Cicero et al. (2014) | 54 SCZ/32 controls | Chapman Scales | Probabilistic Selection Task | People with schizophrenia showed a deficit learning from both positive and negative feedback. These persisted even when given extra trials to learn the reward contingencies. Neither positive nor negative reinforcement learning was associated with anhedonia. | Executive functions and activation/maintenance of representation |
| Cohen and Minor (2010) | 26 studies. | N/A | Meta-analysis. | Patients with SCZ do not differ from controls when rating their subjective hedonic experience to stimuli. | Consummatory pleasure |
| Cohen et al. (2012) | 32 SCZ/25 affective disorder patients/49 high positive schizotypy/32 high negative schizotypy/35 healthy controls. | SANS | Self-reported affective reactions to neutral, negative and positive stimuli. | In both schizotypy and schizophrenia groups negative symptoms were associated with less pleasant reports. | Consummatory pleasure |
| Crespo-Facorro et al. (2001) | 18 SCZ/16 healthy controls | SANS | Studying brain responses to olfactory stimuli using positron emission tomography | Patients failed to activate limbic/paralimbic regions and recruit a compensatory set of frontal cortical regions instead. Ratings of anhedonia did not correlate with blood flow or pleasantness. scores. | Consummatory pleasure |
| Demily et al. (2010) | 21 SCZ/20 healthy controls. | Chapman scales. | Emotional Stroop task. | Slower RTs in SCZ group. No interactions or associations with anhedonia scores. | Executive functions and activation/maintenance of representation |
| Dichter et al. (2010) | 16 SCZ/13 matched controls | SANS | Forced-choice visual oddball task. fMRI | Activation of the anterior cingulate during the task was inversely | Executive functions and activation/maintenance of |

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**Appendix 1** (*continued*)

| Reference | sample size | Negative symptom measure | Method | Findings | TEP model construct |
|---|---|---|---|---|---|
| | | | | correlated with anhedonia. | representation |
| Doop and Park (2006) | 17 SCZ/14 matched healthy controls. | SANS | University of Pennsylvania Smell identification Test (UPSIT) | Pleasantness ratings had a reduced range in SCZ and positively correlated with affective flattening but not anhedonia. | Consummatory pleasure |
| Docx et al (2015) | 40 SCZ/30 matched controls | SANS | Effort Discounting Task | There was no difference between groups in the effort-discounting curves. The effort-discounting in the patient group did not correlate with symptom measures. | Approach motivation and behaviours |
| Dowd and Barch (2010) | 40 SCZ/32 healthy controls | SANS Chapman Scales | Rating valence and arousal to images. fMRI | Higher anhedonia associated with reduced activation to positive vs. negative stimuli in the amygdala and right ventral striatum in patients. | Consummatory pleasure |
| Dowd and Barch (2012) | 25 SCZ/20 healthy controls | Chapman scales | Pavlovian reward prediction paradigm. fMRI | Group level neural responses to anticipation and receipt of reward similar. Individual difference analyses revealed an association between physical anhedonia and activity in the ventral striatum and ventromedial prefrontal cortex. | Executive functions and activation/maintenance of representation |
| Folley and Park (2010) | 18 SCZ outpatients/18 healthy controls. | SANS | Participants indicated which of two photographs of food they preferred and gave hedonic ratings of the pictures. | The use of fewer positive ratings correlated with increased anhedonia. SCZ individuals gave more positive ratings than controls overall. | Consummatory pleasure |
| Franke et al. (1994) | 35 SCZ/26 healthy siblings/35 healthy controls. | Chapman Scales | Continuous Performance Test-Identical Pairs Version | No association found with anhedonia scores in SCZ group or siblings. | Executive functions and activation/maintenance of representation |
| Gard et al. (2007) | Study 1: 10 SCZ+5 schizoaffective disorder/12 healthy controls. Study 2: 50 SCZ+1 schizoaffective disorder/50 healthy controls. | TEPS Chapman Scales SANS | Experience Sampling Methodology Questionnaires | Patients reported similar pleasure levels to controls during goal-directed activities but did them less often. Reduced anticipatory pleasure in clinical group on TEPS which correlated with SANS and Chapman scales. Intact consummatory pleasure. | Anticipatory pleasure |
| Gard et al. (2011) | 28 SZ/19 healthy controls | PANSS | Emotion maintenance task with a 3 s delay between the two viewing phases. Images used. | People with schizophrenia had similar "in the moment" ratings of pleasure but reduced positive and negative affect over the delay period. | Executive functions and activation/maintenance of representation |
| Gard et al. (2014) | 47 SCZ/41 healthy controls | PANSS | Experience sampling methodology—current activity and anticipation of upcoming goals. These were coded independently for pleasure and effort. MATRICS battery | People with schizophrenia set fewer effortful goals and did fewer effortful activities than controls. They also showed greater inaccuracy at estimating the accuracy of goals which was associated with lower neurocognition. Compared to controls people with schizophrenia anticipated higher pleasure from goals and did more pleasure-based activities. | Approach motivation and behaviours |
| Gold et al. (2008) | 8 studies presented: Patients with SCZ and demographically matched controls. | SANS | Reward Processing Tasks e.g. Wisconsin Card-Sorting Task and responses to IAPS images. | Some modest correlations (.3–.4) between performance on these tasks and negative symptoms but most very low. | Executive functions and activation/maintenance of representation |
| Gradin et al. (2011) | 15 SCZ/15 individuals with depression/17 healthy controls. | PANSS | Instrumental reward learning task. fMRI | Reduced prediction error signals observed in schizophrenia but these did not correlate with any negative symptoms. | Executive functions and activation/maintenance of representation |
| Hammer et al. (1995) | 65 SCZ | SANS | Neuropsychological Tests | Anhedonia correlated with preservative errors on the WCST and performance on the word fluency and Trail Making A tasks. | Executive functions and activation/maintenance of representation |
| Harvey et al. (2009) | 29 SCZ/27 matched healthy controls. | Chapman scales | Emotional face recognition memory involving happy, sad and neutral expressions. | No difference in pleasure ratings between controls and people with SCZ. No correlation between social anhedonia and memory performance. | Memory |
| Harvey et al. (2010) | 30 SCZ/26 healthy controls | Chapman Scales | Emotional Picture Viewing Task. fMRI | Anhedonia inversely correlated with activity in the orbitofrontal cortex and putamen/ventral striatum in the patient group. | Consummatory pleasure |
| Heerey and Gold (2007) | 41 patients with schizophrenia or | SANS | Rate IAPS stimuli for valence and arousal. Participants could prolong | Patients with SCZ showed weaker correspondence between their | Approach motivation and behaviours |

**Appendix 1** (*continued*)

| Reference | sample size | Negative symptom measure | Method | Findings | TEP model construct |
|---|---|---|---|---|---|
| | schizoaffective disorder/31 healthy controls. | | or decrease their exposure to certain stimuli in one condition and in the other increase or decrease their likelihood of future exposure to a stimulus. | ratings and their behaviour than controls. | |
| Herbener et al. (2007) | 33 SCZ/28 healthy controls. | Chapman Scales | Emotional ratings of images then 24 hr delay recognition task. | Higher levels of emotional intensity in SCZ group. Reduced recognition for positive images compared to controls, no difference for negative images. | Memory |
| Herbener et al. (2008) | 34 SCZ/35 matched healthy controls | Chapman Scales | Emotional responses to 131 IAPS images. | Emotional ratings and anhedonia scores correlated in both groups. Similar emotional responses in both groups. | Consummatory pleasure |
| Horan et al. (2006) | 30 SCZ outpatients/31 healthy controls. | SANS | Rated emotional responses to food and film clips then a recall task after 4 hr delay. | No difference between SCZ group and control group. | Consummatory pleasure |
| Horan et al. (2010) | 38 SCZ/36 healthy controls. | Chapman Scales SANS | Measured event-related potentials during an affective picture viewing task. | Higher physical and social anhedonia was associated with lower valence ratings for pleasant images. Physical anhedonia correlated with smaller P2 responses in the unpleasant picture condition. No other measures of anhedonia correlated with any other ERP variables. Higher levels of anhedonia correlated with longer viewing times—more top-down influences on emotional processing? | Consummatory pleasure |
| Juckel et al. (2006a) | 10 SCZ typical neuroleptics/10 SCZ atypical neuroleptics/10 matched controls | PANSS | Incentive Monetary Delay Task | In patients treated with typical neuroleptics only reduced activation in the left ventral striatum was associated with negative symptoms. | Executive functions and activation/maintenance of representation |
| Juckel et al. (2006b) | 10 SCZ (7 unmedicated, 3 unmedicated for 2 years)/10 healthy controls. | PANSS | fMRI during presentation of reward-predicting and loss-predicting stimuli in a Monetary Incentive Delay Task | Left ventral striatal BOLD response during reward anticipation was inversely correlated with PANSS negative symptom subscale score. | Executive functions and activation/maintenance of representation |
| Kamath et al. (2011) | 54 SCZ/22 unaffected 1st degree relatives/45 matched healthy controls | SANS | Suprathreshold Amyl Acetate Odour Intensity and Odour Pleasantness Rating Test | Individuals with schizophrenia under-estimate pleasure at low concentrations and over-estimate it compared to controls at higher concentrations. This abnormal pattern correlated with anhedonia/asociality subscale. | Consummatory pleasure |
| Kemali et al. (1987) | 21 male SCZ/19 healthy controls. | SANS | Spatial conditional associative learning task + Non-spatial conditional associative learning task. | No association found between anhedonia and spatial learning. Number of errors and time taken in the non-spatial learning task inversely correlated with anhedonia scores. | Executive functions and activation/maintenance of representation |
| Lacerda et al. (2007) | 43 first-episode, antipsychotic-naive SCZ/53 matched controls. | SANS | Structural MRI | Anhedonia scores correlate with the volume of the left orbitofrontal cortex. | Executive functions and activation/maintenance of representation |
| Larquet et al. (2010) | 21 SCZ/10 orbitofrontal cortex patients/20 healthy controls. | Chapman Scales | Regret Gambling Task | No association between anhedonia and performance on neuropsychological measures. | Executive functions and activation/maintenance of representation |
| Laurent et al. (2000) | 23 SCZ Outpatients,/47 first-degree relatives/34 healthy controls. | Chapman Scales | SPAN, DS-CPT, WCST, Digit Symbol, Trail Making A and B, Stroop task | No associations between performance and anhedonia in the SCZ group. | Executive functions and activation/maintenance of representation |
| Lee et al. (2006) | 21 SCZ/20 controls | PANSS | Valence and Arousal ratings to 60 IAPS images. | Similar emotional experience to controls. No association reported with anhedonia. | Consummatory pleasure |
| Lee et al. (2012) | 14 SCZ/16 healthy controls | Chapman Scales TEPS | Word-image association encoding task. fMRI | Activity in hippocampus and nucleus accumbens when performing association task correlates with physical anhedonia scores. | Executive functions and activation/maintenance of representation |
| Llerena et al. (2012) | 26 studies | N/A | Meta-Analysis of arousal ratings during stimuli presentation. | Controls and people with schizophrenia experience similar arousal levels to unpleasant and pleasant stimuli. People with schizophrenia experience more arousal to neutral stimuli. | Consummatory pleasure |
| Matsuzawa et al. (2015) | 61 SCZ/50 matched controls | SANS | Iowa Gambling Task | People with schizophrenia showed impaired emotional learning—this was dependent on the certainty with which they adopted a strategy for | Executive functions and activation/maintenance of representation |

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**Appendix 1** (*continued*)

| Reference | sample size | Negative symptom measure | Method | Findings | TEP model construct |
|---|---|---|---|---|---|
| | | | | positive gain. The deficit in emotional learning was associated with SANS anhedonia-asociality subscale scores. | |
| Mote et al. (2014) | 88 people with recent-onset schizophrenia diagnosis/66 controls. | TEPS | TEPS administered to examine levels of anticipatory and consummatory pleasure in recent-onset group. | People with schizophrenia reported reduced anticipatory but not consummatory pleasure compared to controls. | Anticipatory pleasure |
| Mucci et al. (2015) | 28 SCZ/22 healthy controls | PANSS TEPS Chapman Physical Anhedonia Scale | Monetary Incentive Delay Task. fMRI | People with schizophrenia with high avolition scores showed reduced dorsal caudate activation compared to patients with low avolition scores and controls. This finding was repeated for patients with deficit schizophrenia compared to non-deficit and controls. Dorsal caudate activity was associated with avolition but not anhedonia in the patient group. | Executive functions and activation/maintenance of representation |
| Oorschot et al. (2013) | 149 SCZ or schizoaffective disorder/143 controls. | PANSS | Experience Sampling Methodology | Patients with high negative symptoms have similar emotional experience to controls, low negative symptom patients more unstable. No association reported with anhedonia. | Consummatory pleasure |
| Park et al. (2009a) | 29 SCZ/21 healthy controls | Chapman Scales | 18 F-fluorodeoxyglucose positron emission tomography | Physical anhedonia correlated in resting state activities of the supplementary motor area, ventromedial and dorsolateral prefrontal cortex, insular gyrus and the precuneus in patients. | Executive functions and activation/maintenance of representation |
| Park et al. (2009b) | 24 SCZ/22 healthy controls | Chapman Scales | Fluoro-D-glucose positron emission tomography | Patients with prefrontal hypofunction showed more severe anhedonia than those without. | Executive functions and activation/maintenance of representation |
| Park et al. (2015) | 20 SCZ/20 matched controls | Chapman Scales PANSS | Deterministic reinforcement learning task with variable intervals of contingency reversals fMRI | No difference in positive or negative reinforcement. Patients showed altered response valuation and initiation-related striatal activity and reduced vACC activation during reward approach initiation. rACC activation correlated with social anhedonia and amotivation. | Executive functions and activation/maintenance of representation |
| Quirk et al. (1998) | 30 SCZ/10 controls | PANSS | Rating valence and arousal to 54 IAPS images. | Average valence slightly lower in SCZ group. No association with anhedonia. | Consummatory pleasure |
| Roux et al. (2010) | 21 patients with SCZ/21 healthy controls. | Chapman Scales | Explicit recognition task and Vocal emotional Stroop task. | Vocal emotional stroop score increased with social anhedonia. | Executive functions and activation/maintenance of representation |
| Sanchez et al, 2014 | 47 SCZ/41 healthy controls | PANSS | Experience sampling methodology—ratings of mood and enjoyment of current activity. MATRICS neurocognitive battery. | People with schizophrenia had higher negative mood but similar positive mood and enjoyment to controls. People with schizophrenia had a weaker relationship between negative mood and current enjoyment of activities compared to controls. Neurocognitive scores mediated this relationship in people with schizophrenia. | Consummatory pleasure |
| Schlagenhauf et al. (2008) | 10 SCZ on typical neuroleptics then again once switched Olanzapine/10 matched controls. | PANSS | Monetary Incentive Delay Task. fMRI | In patients treated with typical neuroleptics decreased left ventral striatal activation was correlated with negative symptoms. | Executive functions and activation/maintenance of representation |
| Schlenker et al. (1995) | 34 male SCZ/24 male healthy controls. | Chapman Scales | Startle-elicited brinks measured during presentation of affective slides. | No difference in patients and controls in subjective or autonomic response to slides. No associations with anhedonia. | Consummatory pleasure |
| Schneider et al. (1995) | 40 SCZ/40 Controls | SANS | Emotion discrimination tasks and mood induction procedures. | Negative correlation present between mood induction scores and anhedonia subscale. No correlation between anhedonia and emotion discrimination. | Consummatory pleasure |
| Simon et al. (2010) | 15 SCZ/15 healthy controls | Chapman Scales | Probabilistic Monetary Incentive Delay Task. fMRI | No significant differences at group level in anticipation or receipt of reward. No associations with anhedonia scales. | Executive functions and activation/maintenance of representation |

**Appendix 1** (*continued*)

| Reference | sample size | Negative symptom measure | Method | Findings | TEP model construct |
|---|---|---|---|---|---|
| Stevens et al. (2002) | 25 SCZ treated with olanzapine, 25 SCZ treated with classic neuroleptics, 25 matched controls. | SANS and SHAPS. | Serial Reaction Tim task, Classic Eye-Blink Conditioning and Explicit Visuospatial Memory Task | No associations with anhedonia. | Memory |
| Strauss and Herbener (2011) | 49 outpatients with SCZ/50 healthy controls. | Chapman Scales | Rating IAPS images on valence and arousal scales. | 60% rated similarly to controls, 40% showed an atypical profile. | Consummatory pleasure |
| Strauss et al. (2011a) | 51 outpatients with SCZ/39 healthy controls. | SANS | Temporal decision-making task—requiring trial-by-trial adjustment to maximise reward. Go NoGo Task. | Individuals with high negative symptoms showed more impairment on Go NoGo than those with low negative symptoms. Uncertainty-based exploration was reduced compared to controls and correlated with anhedonia. | Executive functions and activation/maintenance of representation |
| Strauss et al. (2011b) | 38 SCZ/27 healthy controls. | SANS | Subjects presented with pairs of positive stimuli and asked to indicate which they preferred. | Less differentiation between the valence levels but same pattern of results. | Consummatory PLEASURE |
| Strauss et al. (2014) | 97 SCZ/63 healthy controls. | SANS, Chapman Scales | Victoria Symptom Validity Test to measure effort. WTAR and MATRICS cognitive tests. | Global neurocognitive impairment predicted by low effort and negative symptoms. | Executive functions and activation/maintenance of representation |
| Suslow et al. (1998) | 31 SCZ (predominantly negative symptoms) | SANS | Visual backward masking task, Span of Apprehension task, WCST and degraded stimulus Continuous Performance Test. | Card sorting preservative errors correlated with negatively with anhedonia. No other associations with anhedonia found. | Executive functions and activation/maintenance of representation |
| Szendi et al. (2006) | 13 male SCZ/13 male controls | SANS | Structural MRI + Working Memory Tasks | Anhedonia negatively correlated with the relative volume of the left straight gyrus. No group differences in regions of interest. Anhedonia correlated with performance on the Tower of Hanoi and Corsi Blocks Backwards tasks. | Executive functions and activation/maintenance of representation |
| Trémeau et al. (2009) | 64 SCZ/32 healthy controls. | Chapman Scales | Evocative emotional task with pictures, sounds and words of varying valence and intensity—participants rated pleasantness and arousal. | Ambivalence to positive stimuli correlated with anhedonia in SCZ. | Consummatory pleasure |
| Trémeau et al. (2010) | 70 SCZ/35 controls | SANS | Rating pleasantness and arousal in an evocative emotional task using pictures, sounds and words. Also rating pre-test anticipated pleasure and post-test remembered pleasure. | Emotional experience and anticipated pleasure was similar in both group. Remembered pleasure was higher in SCZ group. Anticipatory pleasure correlated with SANS total but not anhedonia. | Anticipatory pleasure |
| Trémeau et al. (2014) | | | | | Anticipatory pleasure |
| Ursu et al. (2011) | 23 SCZ/24 healthy controls. | SANS | Reporting emotional response to IAPS images after a short delay. fMRI. | Same brain activity in both groups when presented with images. During the delay after pleasant images reduced activation in the dorsolateral prefrontal cortex in patient group was seen which correlated with anhedonia. | Executive functions and activation/maintenance of representation |
| Walter et al. (2009) | 16 SCZ/16 healthy controls. | Chapman Scales | fMRI during a delayed incentive paradigm with monetary rewards. | Dorsal anterior cingulated activation reduced in patient group in expectation phase but no correlations with negative symptom or anhedonia scores. | Executive functions and activation/maintenance of representation |
| Walter et al. (2010) | Study 1:16 SCZ/16 controls Study2: 12 SCZ/12 controls | Chapman Scales | Financial Reward Task | Aberrant salience coding seen in the ventromedial prefrontal cortex of patients with schizophrenia, the degree of this salience coding was inversely correlated with anhedonia scores. | Executive functions and activation/maintenance of representation |
| Waltz and Gold (2007) | 34 SCZ/26 controls. | SANS | Probabilistic reversal learning task. | SCZ group worse at reversal learning but this did not correlate with anhedonia or negative symptoms. | Executive functions and activation/maintenance of representation |
| Waltz et al. (2009) | 18 SCZ/18 healthy controls | Chapman Scales | Passive conditioning task. fMRI | Group differences generally driven by attenuated responses in patient group to positive temporal difference errors (unexpected juice deliveries). No associations reported with anhedonia scores. | Executive functions and activation/maintenance of representation |
| Waltz et al. (2010) | 17 SCZ/17 matched controls. | SANS Chapman Scales | fMRI during monetary incentive delay task. | Significant correlation between activity in the right ventral striatum when viewing a cue predicting reward and anhedonia scores. | Executive functions and activation/maintenance of representation |

(continued on next page)

**Appendix 1** (*continued*)

| Reference | sample size | Negative symptom measure | Method | Findings | TEP model construct |
|---|---|---|---|---|---|
| | | | | Negative symptoms correlate with prefrontal cortex activity in response to gains and losses. | |
| Waltz et al, 2015 | 42 SCZ/44 healthy controls | Chapman Scales SANS BNSS | Sensory-specific satiety paradigm. | Control participants showed an effect of satiety that was sensory-specific, whereas people with schizophrenia did not. Satiety effects correlated with positive and negative symptoms (Chapman physical and social scales and SANS anheodnia/avolition) in the schizophrenia group. | Executive functions and activation/maintenance of representation |
| Woodruff et al. (1997) | Full sample: 42 SCZ/43 healthy controls. Stroop task subsample: 27 SCZ/29 healthy controls | SANS | Structural MRI and modified Stroop Task | Negative correlation between anterior corpus callosum area and anhedonia scores. No association reported for Stroop task performance and anhedonia. | Executive functions and activation/maintenance of representation |
| Wynn et al. (2010) | 34 SCZ/36 healthy controls | Chapman scales. SANS TEPS | Event related potentials (ERPs) and emotional responses whilst viewing images. | Similar patterns of emotional response in both groups. Lower ERPs in patient group. No association between ERP and anhedonia reported. | Consummatory pleasure |
| Yan et al. (2012) | 21 studies state arousal/40 studies state valence/47 studies trait hedonic capacity. | N/A | Meta-analysis | No difference between controls and SCZ in state valence or arousal, lower trait hedonic capacity in SCZ group. Negative symptoms were a significant moderator for the effect size for trait hedonic capacity. | Consummatory pleasure |

## Appendix 2

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| **Title** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| **Abstract** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 1 |
| **Introduction** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 2 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 2 |
| **Methods** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | N/A |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 2 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 2 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 2 |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 2 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 2 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 2 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 2 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | N/A |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | N/A |
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | 2 |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | N/A |
| **Results** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | Figure 2 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | Appendix 1 |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | Appendix 1 |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | N/A |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | N/A |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see item 15). | 15 |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see item 16]). | N/A |
| **Discussion** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 14 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 15 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 14/15 |
| **Funding** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | 16 |

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